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Oil consumption and economic growth: A panel data analysis

Kyoung-Min Lim, Seul-Ye Lim,* and Seung-Hoon Yoo*†
Industrial Technology Policy Center, Korea Institute for Advancement of Technology
*Department of Energy Policy, Graduate School of Energy & Environment, Seoul National University of Science & Technology
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Abstract

Oil is obviously vital for economic growth and industry development. This paper attempts to explore whether or not there is a inverted-U relationship between oil consumption and economic growth. To this end, we employ a panel data analysis with fixed effect or random effect models using the set of data from 61 countries for the year 1990-2008. In conclusion, a statistically significant inverted-U relationship between per capita consumption of oil and per capita GDP is found. However, the level of per capita GDP at the peak point of per capita oil consumption is estimated to be 65,072 in 2005 international constant dollars, which is much larger than economic scales of sampled countries. Thus, as per capita GDP grows, per capita oil consumption is predicted to increase until eventually reaching the peak.

Key words : oil consumption, economic growth, panel data analysis

1. Introduction

Oil has been widely accepted as a vital input to industrial development and economic growth. However, the prospect of future oil consumption has resulted in forecasts of even future wars and high price. Thus, the issue of oil risk has received increasing attention in global in both developed and developing countries. According to 'Energy Outlook 2030' (BPa, 2011), oil is expected to be gradually growing fuel over the next 20 years. Nevertheless, global liquids demand (oil, biofuels, and other liquids) is likely to rise by 16.5 mega barrels per day (Mb/d), exceeding 102 Mb/d by 2030. Furthermore, the growth of liquids demand comes exclusively from rapidly growing developing economies. Developing countries, like China, India, Brazil etc., account for more than three quarters of the global increase, rising by nearly 13Mb/d. However, indeveloped countries, oil consumption increase has been slowed down or oil consumption itself has gradually decreased.

Reynolds (2000) emphasized that oil is the main energy source of large mobile machinery operation and the main driver of economic growth. Thus, Tao (2010) predicted that the oil consumption increases more than twice from 2000 to 2025 in China. In the past several decades, numerous studies have examined the relationship between oil consumption and economic growth. Most of them concern Granger-causality test between the two. For example, Yang (2000), Aqeel and Butt (2001), Fatai et al. (2004), Rufael (2004), Lee and Chang (2005), Zou and Chau (2006), Yoo (2006), Usama (2011) dealt with the issue for Taiwan, Pakistan, New Zealand, Shanghai of China, Taiwan, China, Korea, and the Middle East and North African countries, respectively.

In the recent literature on environmental economics, an important empirical finding has been

†To whom corresponding should be addressed.
Department of Energy Policy, Graduate School of Energy & Environment, Seoul National University of Science & Technology
Tel : 02-970-6802 E-mail : shyoo@seoultech.ac.kr

Table 1. Literature review of environmental Kuznets curve in energy use

	Coefficients		Peak point	Sources
	Income	$Income^2$		
Water	55.67	-0.13×10^{-2}	21,196 (1990 US dollar)	Cole (2004)
Electricity	0.29	-0.24×10^{-5}	61,379 (2000 international dollar)	Yoo and Lee (2010)

the existence of inverted-U relationship between per capita income and environmental indicators (Grossman and Krueger, 1995; Cole et al., 1997; Cole, 2004; Yoo and Lee, 2010). Table 1 summarizes the results for water and electricity consumption. Since this relationship bears to Kuznets relationship between income and energy use, it has been known as Environmental Kuznets Curve (EKC). The mechanisms, used to explain the shape of the EKC (scale, composition, and technique effects), would also seem to apply to oil. We expect the study of EKC to provide at least the direction of the effect of economic growth on oil consumption.

This paper attempts to explore whether or not there is a systematic relationship between oil consumption and economic growth. In particular, we try to ascertain if an inverted-U relationship between the two is statistically significant. The remainder of the paper is organized as follows. Section 2 provides an overview of methodology adopted and explains the data employed here. Section 3 briefly explains the results. Some concluding remarks are made in the final section.

2. Methodology and data

The inverted-U relationship between oil consumption and economic growth is explained in terms of the interaction of scale, composition, and technique effects. The scale effect (S) states that as the scale of the economy increases, *ceteris paribus*, so too will oil consumption. The composition effect (C), however, refers to the fact that as economies develop, there is generally a change in emphasis from heavy industry to light manufacturing and services. Since the latter are typically less oil intensive than the former, the composition effect of growth, *ceteris paribus*, will reduce oil consumption. Finally, there is the technique effect (T). As income rise there is likely to be an increased investment in research and development. The effect of the investment should be to improved energy efficiency and thereby, lowers oil consumption. Fig. 1 provides a hypothetical EKC and illustrates how interaction between S, C and T contribute towards its shape (Cole, 2004; Yoo and Lee, 2010).

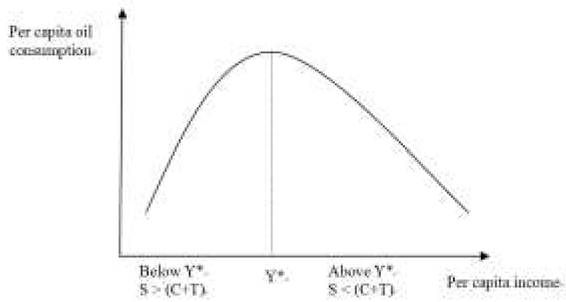

Fig. 1. Hypothetical environmental Kuznets curve

To assess whether such a relation exists between oil consumption and economic growth, the following equation is estimated using a panel analysis.

$$OC_{it} = \alpha_i + \beta_1 Y + \beta_2 Y^2 + \gamma P_t + \epsilon_{it} \qquad (1)$$

where OC refers to per capita oil consumption; Y is per capita gross domestic product (GDP); P is the international oil price; the subscripts i and t refer to country and year, respectively; and is the error term. An EKC is considered to exist if $\beta_1 > 0$ and $\beta_2 < 0$ and both coefficients are statistically significant. Furthermore, to be a meaningful EKC, the estimated peak point, calculated as $-\beta_1/2\beta_2$ (if the oil price will be constant in the future), should be within the per capita GDP range of the sample.

Data covering the period 1990-2008 are used. Per capita GDP data, expressed in 2005 constant international dollars, a measure of purchasing power parity (PPP), come from World Bank (2010). Per capita oil consumption and oil price expressed in terms of barrels/1000 and US dollars per barrel (2010 constant), respectively, were obtained from BP (2011b). However, we exclude several countries (Iran, United Arab Emirates, and Singapore etc.) for having incomplete data. As a result, the sample is made up of 61 countries. Table 2 indicates the sample statistics of per capita oil consumption and per capita GDP.

Our model, Eq. (1), might create omitted variable bias. Thus, the Ramsey's regression specification error test is performed to check if no relevant explanatory variables have been omitted from the regression equation (Ramsey, 1969). The test statistic is estimated to be 2.31 and its corresponding p-value is 0.13. We cannot reject the null hypothesis of no mis-specification in the linear model at the 10% level.

To estimate the parameters given in Eq. (1), we apply panel data analysis using two basic frameworks: the fixed effect and the random effect models. The former takes α_i to be an individual-specific, constant term in the regression model. The latter specifies that α_i is an individual-specific disturbance, similar to the noise ϵ_{it}. The random effect model has the disadvantage of requiring that the correlations between the regressors and individual effects be zero. If α_i is taken to be the same across all the countries, then least squares estimation provides consistent and efficient estimates, α and β. Moreover, for choosing between the fixed effect and random-effect models, we conduct the Hausman test (Hausman, 1978; Greene, 2000). The test checks a more efficient model against a less efficient but consistent model to make sure that the more efficient model also gives consistent results. If the null hypothesis that individual effects are un-correlated with the other regressors is rejected, then we can conclude that fixed-effect model is better choice than the random effect model in a panel analysis.

The test statistic is computed to be 12.70, which is large enough to reject the null hypothesis at the 5 % level, given that its critical value is $\chi^2_{0.05}(2) = 5.99$. We make a choice of the fixed effect model rather than the random effect model in the case of all countries. To further investigate the relationship between oil consumption and economic growth, we segmented the sample into Organization for Economic Cooperation and Development (OECD) and non-OECD countries, and into

Table 2. The sample statistics of per capita oil consumption and per capita GDP over 1990-2008

	Per capita oil consumption (barrels)			Per capita GDP (2005 international dollars, PPP)		
	Mean	Standard deviation	Maximum	Mean	Standard deviation	Maximum
All countries	8.9	6.7	35.3	15,650	11,528	49,416
OECD countries	14.0	5.1	26.7	26,760	7,633	49,416
Non-OECD countries	5.4	5.2	35.3	7,935	6,279	40,599
Developed countries	14.3	5.6	35.3	26,057	7,720	49,416
Developing countries	4.0	2.6	17.3	6,219	3,485	16,418

Sources: World Bank (2010) and BP (2011b).

Table 3. Estimation results of the model

Dependent variable: per capita oil consumption

	All countries	OECD countries	Non-OECD countries	Developed countries	Developing countries
Constant	-	3799.135 (3.50)**	-	4072.071 (3.37)**	1174.781 (2.43)*
Y	0.4731 (10.69)**	0.5549 (9.51)**	0.2703 (3.98)**	0.5518 (9.02)**	0.7043 (6.44)**
Y^2	-0.3636E-05 (-4.90)**	-0.4891E-05 (-4.99)**	0.3435E-05 (2.24)*	-0.47973E-05 (-4.62)**	-0.1987E-04 (-4.42)**
P	-14.4523 (-6.47)**	-21.7948 (-7.19)**	-8.7278 (-2.71)**	-15.5854 (-4.62)**	-13.1738
Peak point	$65,072 (8.11)**	$56,730 (9.30)**	-	$57,517 (8.55)**	$17,723 (6.23)**
Sample size	61	25	36	29	32

Notes: *t*-values are reported in parentheses below the estimates. Peak point expressed in 2005 constant international dollars. ** and * denote the statistical significance at the 1% and 5% levels, respectively.

developed and developing countries, following the classification of World Development Indicator (World Bank, 2010). In the case of non-OECD countries, the Hausman test statistic is estimated to be 10.10. Thus, we can conclude that the fixed effect model is better than random effect model. In the cases of OECD, developed and developing countries, the test statistics are calculated to be 4.70, 0.85 and 0.53, respectively. They are not large enough to reject the null hypothesis at the 5% level. Therefore, the random effect model is applied instead of the fixed effect model.

3. Results

As explained above, we have segmented the sample into OECD and non-OECD, and into developed and developing countries. The estimation results for each case are also presented in Table 3. Some interesting findings emerge from the results. First, the estimates for β_1 and β_2 are positive and negative, respectively, as expected and statistically significant at the 1% level. Thus, we can conclude that a statistically significant inverted-U relationship between per capita oil consumption and per capita GDP is detected in all countries. This implies that the per capita oil consumption grew at a slower pace with the increase in per capita GDP until it reaches a peak point, after which it falls.

Second, per capita oil consumption and per capita GDP show an inverted U-shaped relationship for the most of sampled countries. However, the peak point is calculated to be 65,072, which is greater than the maximum of all countries (49,416). Therefore, per capita oil consumption and per capita GDP, since consumption has not reached a peak point, do not have an inverted-U relationship yet. This shows that the scale effect has been greater than the composition and technique effects for those countries. This finding is similar to that obtained in earlier studies (Suri and Chapman 1998; Agras and Chapman, 1999).

Third, in the OECD countries, a statistically significant inverted-U relationship is found between two. Furthermore, the peak point is computed to be 56,730, which is greater than the maximum of OECD countries. However, it is expected that the economic scales of some OECD countries will soon reach a peak, per capita oil consumption increase at a decreasing rate as per capita GDP rises. The scale effect has been greater than the composition and technique effects. Nevertheless, we expect that the technique effect have increased.

Fourth, in the developed countries, as with the estimation results for OECD countries, the inverted-U relationship is statistically significant and the peak point is calculated to be 57,517. However it is expected that the per capita GDP of developed countries will soon reach a peak as fall thereafter as with the OECD countries. Thus, it appears that per capita oil consumption does have an inverted-U relationship with per capita GDP. In addition, per capita oil consumption grew at a slower pace with the increase in per capita GDP, declining after reaching its peak.

Fifth, in the developing countries, a statistically significant inverted-U relationship is observed. The peak point is computed to be 17,723, which is greater than the maximum of developing countries (16,418). Per capita oil consumption increase at a decreasing rate as per capita GDP rises. However, in non-OECD countries, it appears that per capita oil consumption increases at an increasing rate with per capita GDP. Therefore, the inverted-U relationship does not appear. The difference between developing countries and non-OECD countries is whether four countries (Hong Kong, Israel, Saudi Arabia, and Trinidad and Tobago) are included or not.

Thus, it appears that per capita oil consumption does have an inverted-U relationship with per capita GDP. It increases at a decreasing rate with per capita GDP rises until eventually reaching a peak, thereafter falling. However, a peak is much larger than current economic scale except a few countries (Norway, United States etc.). Furthermore, non-OECD regions are predicted to experience an increase, per capita oil consumption for many years to come, in line with economic growth. As a result, total oil consumption is expected to increase significantly for a considerable period, given the rapid population growth in most developing regions.

4. Concluding remarks

This paper attempted to clarify whether there is a systematic inverted-U relationship between oil consumption and economic growth. Evidence of such a relationship has been provided, suggesting that oil consumption appears to benefit from composition and technique effects. The results show that a statistically significant inverted-U relationship was found, and the peak point was computed to be 65,072 in 2005 constant international dollars, PPP. The level per capita GDP at the peak of per capita oil consumption is greater than the maximum of all the countries (49,416). Thus, as per capita GDP grows, per capita oil consumption is predicted to increase in the future until eventually reaching the peak.

Although oil consumption is predicted to increase in the future, oil production will gradually decrease due to the exhaustion of natural resources. It constrains to investment the new technologies for reducing oil consumption or for oil drilling in the world. We expect that the investment of such technologies has the effectiveness, since oil consumption appears to benefit of the composition and technique effects as we found. Finally, the policy for research and development expenditure needs to invest in so-called green technologies and to scale up their presence, and therefore developed technologies are helpful the composition and technique effects greater than the current.

Moreover, the disparity between developed and developing countries in techniques expands the dispensable oil consumption in developing countries. To provide technical supports to developing countries will be also helpful to mitigate the increase of oil consumption. The supports are important, because the oil consumption of developing countries accounts for more than three quarters of the global increase.

Considering the results from another angle, if oil prices increase sharply, the peak of oil consumption will be lower than the estimated values because the price elasticity is elastic. This may be explained that the consumer use the alternative fuels like natural gas, coal etc., or replace fuel efficient machines like hybrid cars. However, if oil prices do not eventually increase and maintains the status quo, oil consumption gradually increases because the estimated peak points are at income levels that have been surpassed in all countries. Consequently, the police markers need to prepare a policy against sudden price change and consumption increase for quite some time.

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